Global Warning
Designing an Original Arcade Game for a Music Festival Audience

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Abstract

This thesis presents the development and analysis of *Global Warning*, a physical computing game designed for a music festival audience. The game employs an arcade style because coin-operated games have a rich history of entertaining crowds in the public forum. Based on defining characteristics of games in this tradition, five design pillars were established to guide *Global Warning*'s development – Attention Grabbing, Simple and Accessible, Quick and Exciting, Replayable, and Social. Cooperation mechanics and asymmetric player roles provide a foundation for gameplay, while unique hardware controllers, dazzling lights, and a novel wooden display are focal points of the construction. The project emerged from a workshop at Aalto University called Alt+Ctrl+Aalto, where students were invited to create handmade, physical computing games for Flow Festival, a popular arts and music festival based in Helsinki.

This thesis begins with an introduction to the game, its designers, and the motivations behind its development. It then presents a brief history of the arcade, from early coin-operated amusements to modern indie experimental games. Next, it comprehensively examines the game design process, analyzes the game’s successes and failures based on data collected at Flow Festival, and suggests improvements that are implemented into a second iteration of the game. This thesis concludes with a discussion of key learnings and offers some recommendations to future developers.

Keywords arcade, asymmetric gameplay, game design, physical computing, music festival
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Chapter 1

Introduction

In April of 2018, I began working on a physical computing prototype that would later become the arcade game Global Warning. As part of a team of two, my main duties were game design and programming, along with the shared responsibilities of cabinet design and construction. The project emerged from a workshop at Aalto University where students were invited to create handmade, physical computing games for Flow Festival, a well-known arts and music festival based in Helsinki. The purpose of this thesis is to describe and evaluate how the game was designed to engage a diverse music festival audience.

To guide the game design process, design pillars were established based on key characteristics of Golden Age arcade games and coin-operated amusements of the early 20th century. Collaboration mechanics and asymmetric player roles provide a foundation for gameplay, while unique hardware controllers, dazzling lights, and a novel wooden display are focal points of the construction. The first iteration of the game was presented at Flow Festival in August 2018, where it was played by hundreds of attendees. Improvements were then made based on data gathered during these play sessions, and in May of 2019, the game’s second iteration (its current form) was completed. Since then it has been featured in multiple arts and music festivals, including Kontula Electronic in Helsinki and Sónar+D in Barcelona, and has been played over 5000 times.

This chapter serves as an introduction to Global Warning and an overall blueprint for this document. First, it offers a description of the game and introduces the design team and their roles. Then, it establishes the project sponsors and their objectives. Next, it presents the central research question and design pillars of the game. Finally, the chapter ends by outlining the scope and structure of this thesis.

1.1 Game Description

Global Warning is a two-player cooperative arcade game where players defend Earth from an onslaught of solar energy. Solar energy takes the form of randomly colored LED projectiles that hurdle from the edge of screen towards Earth in the center. To deflect solar energy, players share control of a light shield, which rotates around the Earth. One player has the ability to move the shield, while the other can change its color. For a successful deflection, the shield must match a projectile’s position and color, a mechanic that forces cooperation through interdependence. Each missed projectile damages Earth, and if it happens too many times, it explodes into flames and the game is over. A gameplay demonstration can be viewed here for reference [link].

The game design of Global Warning draws inspiration from the classic arcade games Pong and Breakout. However, it also brings several new twists to the genre. While traditional paddle-and-ball games feature competitive gameplay and symmetrical player abilities, Global Warning is a cooperative game with asymmetric player roles. The game’s controllers
are also unusual and would typically be found in industrial machinery: a rotating handwheel and four-directional switch joystick. Another differentiating feature is the game's lack of a standard digital display. A custom one was built from LED lights and wood veneer, which creates a unique visual experience (Figure 1).

Cabinet construction is reminiscent of cocktail arcade game cabinets of the 1980s, complete with cupholders and flat tabletop display. Players stand beside the game at individual controller boxes and look down to the shared playspace. Turning the handwheel controller rotates the shield's position, while four-way switch changes the shield's color. The playspace consists of a pulsing light in the center, which represents Earth, surrounded by a ring of LED lights, which represents the shield. Radiating outward are eight LED strips, the lanes along which solar projectiles travel towards Earth.

The *Global Warning* design team consisted of Caleb Rugg and Bryant Hoban, both of whom are students in the New Media program at Aalto University. Caleb, the author of this thesis, oversaw the game design and programming of *Global Warning*, while Bryant managed the electronics and sound design. Cabinet design and construction was done collaboratively. We were advised by Robin Baumgarten, an independent game designer known for using experimental hardware controllers, and Matti Niinimäki, a Helsinki-based media artist and lecturer at Aalto University. The game was first conceptualized during a game design and physical computing course led by Baumgarten and Niinimäki. Niinimäki was also an advisor on this thesis.

![Figure 1: Image highlighting the game's novel display and mechanical controllers (Caleb Rugg).](image-url)
1.2 Motivations

The development of *Global Warning* arose from several intrinsic and extrinsic motivations. On a personal level, my coursework within the New Media department had inspired a dual interest in game design and physical computing. This led me to enroll in a workshop called Alt+Ctrl+Aalto. The workshop was a joint collaboration between the New Media department and Flow Festival, and the intended outcome was an exhibition of physical computing games made by students. The exhibition would debut at Flow Festival, which sought a games-focused attraction for guests. This aligned with the university’s goal of bringing more visibility to their game design program. The following section gives more detail on the motivations behind the development of *Global Warning*.

Before attending Aalto University, my education and professional background centered on film and video production. I obtained a Bachelor of Fine Arts (BFA) from The Film School at Florida State University, and afterwards I moved to New York City to work in the industry. When I first arrived, I worked in various freelance positions as I tried to establish myself – production assistant, set decorator, grip and lighting, even special effects makeup. Later on, I was employed by a digital studio for several years, directing and producing weekly web shows and other branded content. In my spare time, I also pursued personal projects, such as short films, music videos, and comedy sketches. Eventually, however, I developed an interest in interactivity, an aspect that traditional media sorely lacked, so I enrolled in Aalto’s New Media program to explore this passion further.

In Aalto’s eclectic program, I discovered many new creative outlets centered around storytelling and interaction. I gravitated towards game design especially, taking classes within both the Game Design and Production major and Computer Science department. In these classes, I worked on three video game projects and two virtual reality experiences. One of the games, *Cage Carnage*, was a multiplayer first-person shooter based on the feel and mechanics of *Quake III Arena*. Players compete as bloodthirsty hamsters who battle to the death inside their cage, utilizing shotguns, laser cannons, and poop bazookas. *Labyrinth* was a large, virtual reality maze where players had to navigate their way to the top of a pyramid, climbing rope ladders and finding hidden treasure along the way.

While these works were entirely digital, I also began exploring physical computing projects and interactive art installations. One of them was *The Living Dollhouse*, which was a miniature Victorian dollhouse inhabited by lifelike holographic projections. Another interesting project was the *Emoji Glove*, a wearable device prototype that converted a user’s hand gestures into text messages and delivered them via Bluetooth.

In the spring of 2018, an opportunity arose to synthesize these two passions. The New Media department established a game design and physical computing course called Alt+Ctrl+Aalto. The purpose of this course was to examine playful interactive experiences using alternative controllers and create an exhibition of original games for the 2018 Flow Festival. During the course, we explored different sensors, microcontrollers, and experimental tangible interfaces. There was also a workshop component led by Robin Baumgarten, an indie game developer who specializes in unconventional hardware controllers and LED-based installation games. During this workshop, we built the first
prototype of *Global Warning* and pitched it to representatives from Flow Festival.

In order to be included in the exhibition, games needed to meet certain criteria. Environmental responsibility has always been a key driver for Flow, so games had to promote a message of sustainability. Festival organizers expected over 80,000 attendees, so games needed to be quite robust as well, especially the controllers and user interface. The nature of the exhibition itself also created some special design concerns. Games would reside in an outdoor pavilion for the duration of the festival, so strong weatherproofing was required. We addressed these requirements to their satisfaction in our proposal, and over the next three months, we constructed a full version of *Global Warning*.

### 1.3 Research Question and Design Pillars

The unique circumstances of the project precipitated one central research question, which is the focus of this thesis: How can a physical computing game be designed to engage a diverse music festival audience?

To help answer this question, I looked to the rich design tradition of arcade games and other coin-operated amusements. These co-located, physical games have a long history of entertaining crowds in public venues, and over time, certain design characteristics have emerged. Drawing from this rich history, I established five design pillars to guide the game’s development. Personal experience provided some insight, as well. I spent a lot of time playing in arcades as a child and teen, giving me firsthand knowledge of many classic games. I had also attended Flow Festival in years previous, providing a window into the setting, crowd, and atmosphere.

Throughout the history of arcade games, certain design characteristics have emerged. Andrew Williams provides an excellent summary in his book *History of Digital Games*:

> Nearly one-hundred years before the first appearances of digital arcade games, both mechanical engineers and artists created games designed to be visually attractive, easy to understand, and difficult or outright impossible to master. These design concepts were conditioned by a business model that centered on making money by having a high volume of customers pay low prices per trial. As such, the games would only be financially successful if play could start immediately and conclude quickly. While impossible to establish the absolute origin of these concepts, they are intimately connected to playing games in public spaces and are best illustrated by carnival games and games played on the midways of fairs. Combined with the very human desire to win or redeem one’s self after failure, these ideas led to some of the most memorable, enjoyable, and profitable gameplay experiences of the nineteenth and twentieth centuries.¹

To fit the game firmly within the arcade tradition and answer my central research question, I established the following five design pillars:

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• Attention Grabbing
Music festivals are boisterous and dynamic events, with many exciting attractions vying for attention. In order for the game to have any chance at success, it needed to stand out visually and possess a wow factor that attracted potential players. Historically, arcade games and other such amusements employed flashing lights and animation, loud sound effects and music, and eye-catching design to do so. *Global Warning* would need to emulate these games in order to fit within the festival environment and compete for attention.

• Simple and Accessible
With Flow expecting 80,000 attendees from all over the world, players would be highly diverse. That meant major differences in age, skill, experience, and interest. Even a common language to explain the game was unlikely. Although pleasing everyone was impossible, our goal was to create a game that engaged as many as possible. For that reason, it needed to be simple and accessible, with intuitive controls and straightforward rules. According to Nolan Bushnell, founder of Atari and inventor of *Pong*, “All the best games are easy to learn and difficult to master. They should reward the first quarter and the hundredth.”² In fact, Bushnell’s classic *Pong* had only six words of instruction: Avoid missing ball for high score.³ Making a complex game that required too much skill and dexterity would severely limit our potential audience.

• Quick and Exciting
The primary draw at music festivals are, of course, the musical performances. Everything else is a secondary attraction and only explored in between sets or as a change of pace. Consequently, potential players would have limited time and focus for a new game. Slow and ponderous games like chess or *Settlers of Catan* would not be ideal at an event like Flow. It was also important that the game match the emotion and intensity of the festival setting. Therefore, we established “Quick and Exciting” as another key design pillar. Two minutes was our target session length, and we wanted those sessions to be highly energetic and action-packed. Short play sessions align with tradition, as well. They have always been an integral part of the business model of arcade games, which rely on a steady stream of quarters to generate income. Quick games create faster turnover and thus the opportunity for more paying players.

• Replayable
Replayability is the hallmark of a good game. Rarely, if ever, are classics played once and discarded. For arcade games though, it is also a necessity, as they depend on players returning again and again to insert more coins. In his article on arcade-style game design, DeLeon has this to say:

> Skill in arcade games has more to do with reaction and timing than it does physical performance or pure strategy. These games tend to be made for high replay value – designed for repeat enjoyment, even though presenting the same

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³ Ibid.
content each time. A

Our game would be free of charge, but it was still important to design with replayability in mind. It fit with convention, but above all, we wanted to create an experience that delighted players the first time as well as the hundredth.

- Social

Music festivals are highly social events. People often come with friends for the purpose of creating memorable shared experiences. They also might attend to meet others with similar interests. In order for our game to thrive within a festival environment, we needed to accommodate this motivating factor.

By adhering to these design pillars, we hoped to find a satisfactory answer to our central research question and create an engaging physical computing game for a music festival audience. One can look at these five design pillars and see that they make sense in a “big picture” context. First, the game needed to attract players and allow them to play with ease (Attention Grabbing, Simple and Accessible). Next, it needed to be engaging and match the festival atmosphere (Quick and Exciting, Social). And finally, to have any chance at success, the game needed enduring appeal (Replayable).

1.4 Thesis Scope and Structure

Design is creative problem solving, and while designers strive for an optimal solution, it is often more about finding one that works. This holds especially true for games, as designers contend not only with real-life limitations but also with players’ disparate tastes. Even with infinite time and resources, it is likely impossible to design a perfect game that appeals to everyone. This thesis explores one approach to designing a game for a music festival audience, while also working within the parameters set by festival organizers. It does not claim to be the only way or the best way of doing so. In fact, a variety of other games and interactive experiences were developed within the same workshop as Global Warning and exhibited at Flow. What makes Global Warning noteworthy are its game design and key learnings, both of which this thesis will discuss in detail. Specific topics such as coding, tools, and implementation details will not be the focus, so that more attention can be given to major design decisions and why certain choices were made. Our methods, observations, and outcomes will also be presented in the hope they benefit other designers.

The next chapter presents a brief history of the arcade, from the birth of coin-operated amusements to modern indie maker culture. It establishes a context for the development of Global Warning and embeds it within the arcade tradition. Chapter three describes our methodology, and chapter four comprehensively examines the game design process. Chapter five analyzes the player data collected at Flow and outlines improvements made as a result. Chapter six concludes this thesis with a discussion of key learnings and offers some recommendations to future game developers.

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Chapter 2

A Brief History of Arcade Games

By illuminating the history of arcade games, this chapter provides some context for *Global Warning*. It starts in ancient Greece with the advent of coin-operated machines, then continues through the Medieval Period into the 19th century, when mechanical novelties became ubiquitous. Next, the chapter moves into the 20th century, when penny arcades elevated these machines from sideshow feature to main attraction. This continued into the "Golden Age" of the 1970s and 80s, when companies like Atari propelled arcade video games into the cultural zeitgeist. After years of success, however, oversaturation and home gaming consoles crashed the industry, and arcade games faded in popularity. The chapter ends by discussing the contemporary revival of arcade game design among the independent maker community, brought on by the availability of low-cost, easy-to-use electronics (along with a fair amount of nostalgia). It is within this group that *Global Warning* finds its peers.

2.1 Early Amusements

Modern arcade games hail from a long history of coin-operated machines. The first such machine dates back 2,000 years to the Greek city of Alexandria, when inventor and mathematician Heron designed a device that dispensed holy water for a five-drachma sum.5 Many temples also featured steam-operated organs and self-opening doors that were activated by the payment of a coin.6 During the Medieval Period, European watchmakers adapted their knowledge to create mechanical amusements called *automata*.7 These varied considerably in form, from mechanical singing birds to animated demons that scared churchgoers with grotesque expressions.8 Over the centuries, automata advanced significantly. In 1784, Marie Antoniette was given a tiny porcelain likeness of herself that was capable of playing eight different melodies on a miniature dulcimer.9 Another was Henri Maillardet’s *Draughtsman-Writer* from 1805, which could reproduce three "handwritten" poems and four detailed drawings.10

By the 1890s, coin-operated amusements were ubiquitous. The Second Industrial Revolution had created a populace with more time and money to spend on leisure.11 Travelling showmen kicked off the craze, bringing novelty machines to country fairs in the

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6 Ibid.
8 Ibid.
summer and vacant shops in the winter. These machines came in a variety of forms: fortune tellers, shooting galleries, waxwork figures, exercise machines, kinetoscopes, and peepshows (Figure 2). Initially, these novelties were placed outside fairs or in storefront windows with the intention of luring passersbys to a main attraction, but soon enough, they were the main attraction. Shops devoted solely to coin-operated amusements quickly sprouted up all over Europe and North America. By the early 1900s, London alone had over 170 arcades.

![Figure 2](image-url)


Popularity surged well into the 20th century, fueling an explosion of new novelties, amusements, and games. The industry was booming, and the future was bright. Herbert Mills, owner of the Mills Novelty Company in Chicago, had this to say in 1907:

The Arcade is no longer an experiment... The Penny Arcade has become a permanent institution as much as the theatre, the opera, the circus, the concert, the lecture, or the gymnasium, for it combines in a modified form all of these and because it makes such universal appeal, particularly to the poorer classes, it is destined to grow constantly in popularity and size... I put in 141 arcades last year and many of them are making more than 100 percent. I am going to install five hundred this year through the West and Middle West.14

Over the next half century, electromechanical games increased in popularity. Strength testers, pinball, racing games, sports games, and more emerged and developed rapidly (Figure 3). These machines would lay the foundation for modern digital arcade games in two important ways. First, many of them were multiplayer experiences, which was a key development for games in public spaces.15 Also, for the first time players were not competing with their physical bodies but through representations known as avatars, a feature still common in video games today.16 Despite their impact, however, electromechanical games would soon be replaced by digital ones, as the computer revolution of the 1970s took hold.


14 Costa, Automatic Pleasures, 29, 33.
15 Williams, History of Digital Games, 10.
16 Ibid.
2.2 The Golden Age and Decline

In 1968, Nolan Bushnell was an electrical engineering student at the University of Utah, and during summers, he worked at a local amusement park as head of games. While overseeing carnival games and coin-operated machines, he learned the economics of the arcade. He knew which games attracted the most customers and how much money they needed to earn in order to be profitable. At the same time, Bushnell had access to the computer technology being developed at his university. Years later, Bushnell explained how these dual experiences inspired him:

I was playing games on the big computers when I was in school. In summers I was working in the arcades. I knew what an arcade game cost. I knew how much it had to earn. I really understood the economics of the coin-operated game business, and I think that I was perhaps the only person that had those two experiences, which allowed me to synthesize it.\(^\text{18}\)

In 1972, Bushnell co-founded Atari. Later that year, Atari released *Pong*, and the game’s massive success changed the industry forever.\(^\text{19}\) A single machine could generate $40 per day, and within two years they had sold over 4,000 machines.\(^\text{20}\) This caused manufacturers, distributors, and venues to shift focus from mechanical games to digital ones. These new games were easier to produce and cheaper to maintain because unlike pinball or mechanical football, digital games had no expensive moving parts.\(^\text{21}\)

The next decade saw the release of some of the arcade’s most iconic games: *Space Invaders*, *Asteroids*, *Pac-Man*, *Donkey Kong*, *Mario Bros.*, and *Galaga*. This period of rapid growth and exceptional creativity in the video games industry is often referred to as the “Golden Age” of arcade games. In the United States, the number of arcades reached a peak of 10,000, and in 1981 the industry’s income was estimated at $5 billion.\(^\text{22}\) Success was short-lived, however, as a gold rush mentality caused the market to become oversaturated with low quality, unoriginal games. By 1983, more than 2,000 arcades had shuttered, and the industry reported a loss of $1.5 billion.\(^\text{23}\)

In addition to an oversaturated market, the development of home console gaming and the affordability of personal computers also contributed to the decline of arcades.\(^\text{24}\) In the late 1980s and early 90s, fighting games like *Street Fighter II*, *Double Dragon*, and *Final


\(^{18}\) June, “For Amusement Only.”

\(^{19}\) Williams, *History of Digital Games*, 58.

\(^{20}\) June, “For Amusement Only.”

\(^{21}\) Ibid.


\(^{23}\) Wolf, *Encyclopedia of Video Games*, 149.

Fight would occasionally revive the industry, but it was never for long. Arcades had become unsustainable. Computer games and consoles were more convenient for players, cheaper to distribute, and required less overhead than rental space and machine maintenance. By the late 1990s, arcade games were mostly a novelty, relegated to the back corner of bowling alleys, comic book shops, and mall food courts.

2.3 Modern Resurgence

In recent years, the arcade has undergone a modest revival. The primary driver of this growth has been an adapted business model, although technological advances and nostalgia have also contributed. Dave & Buster’s, for example, is a popular chain of North American arcades that relies on all three. The company markets itself as a family-friendly and professional venue, distancing itself from the stereotypical image of the arcade as a grungy teenage hangout. In addition to a large game room, each Dave & Buster’s location features a full-service restaurant and sports bar, which generates over 40% of their yearly revenue. Expanding the business in this way has enabled Dave & Buster’s to thrive, accommodating everything from children’s birthday parties to corporate events. Another key to their success is technology. No longer accepting loose change, all games have been retrofitted with card readers and touchscreens, enabling cashless payment and variable pricing, food and beverage sales, loyalty programs, and analytics data. This has allowed Dave & Buster’s to create a more tailored experience for players and turn each machine into a point-of-sale opportunity. Although it’s more of a hybrid concept than traditional arcades, these adaptations have modernized the arcade business and allowed it to become more financially sustainable.

Another example of a successful, contemporary arcade (and a particular favorite of mine) is Barcade. Barcade is a combination bar and arcade with a focus on classic arcade games and American craft beer (Figure 4). The first one opened in Brooklyn in 2004, and the company has since expanded to eight additional locations. It caters more to the young bar crowd than Dave & Buster’s and features a wide selection of familiar, Golden Age-era machines. While Barcade makes a majority of its money on alcohol sales, what draws customers in are its classic games. Barcade taps into a childhood nostalgia and creates a unique playspace for adults. This has allowed it to stand out and excel in the hyper-competitive New York bar scene. Following the success of Barcade, hundreds of new arcade bars have opened across the United States. Earlier this year, in fact, I attended a similar venue in Florida called Lowry Barcade, which opened in 2016 and describes itself as

Tampa’s first arcade and craft beer bar. Extrapall Pelihalli is one based here in Helsinki that features dozens of vintage pinball machines and early mechanical games.

Another recent development in the evolution of arcades is the emergence of handmade, independent games by artists and designers within the maker community. This phenomenon has been fueled by the availability of low-cost, powerful electronics, open source hardware and software, and online learning resources. Companies like Arduino, the Raspberry Pi Foundation, and Adafruit Industries have empowered enthusiasts to develop their own physical computing games. The knowledge and tools have been democratized, and arcade game production is no longer restricted to the assembly line. With some additional carpentry knowledge, a simple arcade cabinet can be constructed. Affordable ones can also be purchased online. This accessibility has allowed many new perspectives to enter the space, leading to an explosion of creativity and experimentation that is redefining what an arcade game can be.

Robin Baumgartner, who led the workshop where Global Warning was developed, has been particularly innovative, especially in terms of presentation and user interface. His game Line Wobbler is a one-dimensional dungeon crawler visualized on a several meter-long LED-strip display. It also features a unique “wobble controller” made from a door-stopper spring. BumbleBear Games is a boutique design studio pushing the limits of the medium with their game Killer Queen. Killer Queen is an action strategy game designed to be the centerpiece of any arcade. Its massive, double-sided cabinets support ten players at once, creating an exciting and chaotic experience. Love Hultén is a Swedish designer whose work fuses traditional craftsmanship with modern technology. He builds highly polished, retro minimal housing for emulator games, and his work was a significant inspiration for Global Warning’s cabinet design. Other notable artists and collectives making experimental arcade games are Mark Kleback, Gregory Kogos, James Medd, Juno Morrow, Andy Wallace, We Throw Switches, and Death By Audio Arcade. These artists – along with many others – also develop games in a more traditional arcade style.

Alongside this movement of handmade games, independent arcades have emerged to showcase them. Wanderville is an indie arcade gallery and bar in Brooklyn with more than 20 games in its collection, including Line Wobbler and Killer Queen (Figures 5–7). Awkward Arcade and We Throw Switches host regular events in the UK that highlight independent arcade games, as well (Figure 8). Media channels have also developed to support the community. Indie Arcade Wave, for example, is a podcast exploring indie arcade games, arcade bars, and music that comes from the arcade. Each week it spotlights a new game, artist, developer, arcade or other member of the community. It is within this community that Global Warning hopes to find its place and peers.

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Figure 5: Wonderville in Brooklyn, which showcases independent arcade games. (Wonderville, “LinkedIn – Company Profile – Wonderville – About,” accessed 9 October 2020, https://www.linkedin.com/company/wonderville/about/)


Figure 8: Gregory Kogos’ *RotoRing*, featured as part of We Throw Switches alt arcade. (We Throw Switches, “Alt.Arcade Cabinets,” accessed 9 October 2020, https://www.wethrowswitches.com/altarcade).
Chapter 3

Methodology and Development Process

Our primary goal with *Global Warning* was to develop an original physical computing game that engaged a wide-ranging music festival audience. We also needed to adhere to the design requirements set by Flow Festival and Aalto University's Alt+Ctrl+Aalto workshop. These were mainly practical considerations like budget, construction materials, physical dimensions, and, of course, deadlines, although there were also a few content-related requests. One was that the game’s overall theme impart a message of sustainability. Another was that the game utilize alternative hardware controllers. To guide the development process further, five design pillars were established based on defining characteristics of arcade games. These pillars were Attention Grabbing, Simple and Accessible, Quick and Exciting, Replayable, and Social. All of these considerations formed the constraints within which we would work. Next, we implemented an iterative design methodology to drive the process forward. That methodology is discussed in more detail in this chapter.

3.1 A Bilateral Approach to Iterative Design

Game design is a complex endeavor. The interactive nature of games makes it difficult to anticipate the myriad ways in which players will experience or interpret them. What is simple or intuitive for one may be confounding to another. What is exciting for some might be frustrating or boring for the rest. The best that designers can do is take incremental steps forward through iterative cycles. Problems are identified and researched, solutions are proposed and tested, data is analyzed, and then the problem is re-evaluated. If the issue was solved, then on to another; if not, then time to test a new idea. Either way, the cycle begins anew. This overall process is called iterative design, and it was crucial to the development of *Global Warning*.

During the development of *Global Warning*, we instituted an iterative design process informed by regular playtests and well-established game design heuristics. During playtests, data was collected through empirical observation and informal interviews. Understanding that data collected in this manner can be subjective and open to interpretation, we also referenced a set of game design heuristics to help us analyze and validate the information we received. Together, these tools created a bilateral approach to iteration.

During the playtests and informal interviews, personal and demographic information was never recorded during playtest sessions, thus preserving users’ anonymity. A majority of participants knew they were being observed and gave express permission, although at large public events like Flow, sometimes that was not possible. Permission was always obtained from parents, however, when observing children. Observations were recorded primarily by hand or with a smartphone application for note taking. These were later compiled into a larger document, organized by play session.
While players interacted with the game, we documented their actions and demeanor. We also noted the game events that caused them. Afterwards, we would discuss the experience with players. We would ask open-ended questions as much as possible and let them answer in their own words. Sometimes feedback was clear and conclusive, but often it was ambiguous. Also, due to the hectic nature of some playtest settings, we could not always perform in-depth interviews or observe full play sessions, leading to incomplete datasets and unclear steps forward. In situations like these, well-established game design heuristics offered clarity. Consulting them helped us evaluate the information we had, prioritize issues, and guide us toward possible solutions. The set of heuristics we followed was Sweetser and Wyeth’s GameFlow model (Table 1), which adapts Csikszentmihalyi’s concept of flow experience to games so that player enjoyment can be evaluated.\(^\text{30}\) Below is an example illustrating how our process might work:

**Observation:** A player interacts with the game for the first time. He struggles initially but then seems to understand how to play. He operates the controls correctly and makes several deflections in a row. Then, the speed of the game increases, and the player cannot keep up. He fails to make a deflection, triggering the game over animation. He moves the controller back and forth and says, “Wait, what’s going on? Is it over already?”

**Interviewer question:** You seemed confused at the end. What happened?

**Player Answer:** I thought I was doing well, then I missed and the game just ended. I didn’t expect that. Oh well, I need to go now. Fun game!

**Heuristic Violated:** Feedback – *Players should always know their status or score*

**Possible Solution:** Communicate more clearly to players what their remaining life total is.

In the above example, while the player seemed to understand the core gameplay, something confused him during the endgame sequence. An open-ended question revealed that he expected the game to continue and did not understand why it ended. At this point, the interview was cut short and no follow-up questions were asked. Consulting the GameFlow model with the information we had, we found a possible explanation for the issue and constructed a solution. At this point, it would be important to observe and interview more players, focusing specifically on how they react to the endgame sequence. This would allow us to validate the issue, understand its prevalence, and determine the priority for fixing.

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
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<tbody>
<tr>
<td><strong>Concentration</strong></td>
<td>- Games should provide a lot of stimuli from different sources&lt;br&gt;- Games must provide stimuli that are worth attending to&lt;br&gt;- Games should quickly grab the players’ attention and maintain their focus throughout the game&lt;br&gt;- Players shouldn’t be burdened with tasks that don't feel important&lt;br&gt;- Games should have a high workload, while still being appropriate for the players’ perceptual, cognitive, and memory limits&lt;br&gt;- Players should not be distracted from tasks that they want or need to concentrate on</td>
</tr>
<tr>
<td><strong>Challenge</strong></td>
<td>- Challenges in games must match the players’ skill levels&lt;br&gt;- Games should provide different levels of challenge for different players&lt;br&gt;- The level of challenge should increase as the player progresses through the game and increases their skill level&lt;br&gt;- Games should provide new challenges at an appropriate pace</td>
</tr>
<tr>
<td><strong>Player Skills</strong></td>
<td>- Players should be able to start playing the game without reading the manual&lt;br&gt;- Learning the game should not be boring, but be part of the fun&lt;br&gt;- Games should include online help so players don’t need to exit the game&lt;br&gt;- Players should be taught to play the game through tutorials or initial levels that feel like playing the game&lt;br&gt;- Games should increase the players’ skills at an appropriate pace as they progress through the game&lt;br&gt;- Players should be rewarded appropriately for their effort and skill development&lt;br&gt;- Game interfaces and mechanics should be easy to learn and use</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>- Players should feel a sense of control over their characters or units and their movements and interactions in the game world&lt;br&gt;- Players should feel a sense of control over the game interface and input devices&lt;br&gt;- Players should feel a sense of control over the game shell (starting, stopping, saving, etc.)&lt;br&gt;- Players should not be able to make errors that are detrimental to the game and should be supported in recovering from errors&lt;br&gt;- Players should feel a sense of control and impact onto the game world (like their actions matter and they are shaping the game world)&lt;br&gt;- Players should feel a sense of control over the actions that they take and the strategies that they use and that they are free to play the game the way that they want (not simply discovering actions and strategies planned by the game developers)</td>
</tr>
</tbody>
</table>
Table 1: Sweetser and Wyeth’s GameFlow Model for Evaluating Player Enjoyment in Games.\textsuperscript{31} We consulted these game design heuristics to better understand our playtest data and identify potential solutions.

### 3.2 The Course of Development

The development of *Global Warning* can be divided into three major releases: the proof-of-concept prototype, the Flow Festival version, and the post-Flow update. There were numerous minor improvements and iterative steps between them, but for the scope of this document, these are the project’s key milestones. The proof-of-concept prototype was completed in May 2018 while participating in Robin Baumgarten’s Alt+Ctrl workshop. It was then presented to members of Aalto University’s Marketing and Brand team, as well as representatives from Flow Festival. Upon their approval, budget and resources were allocated for the production of a full version. This was completed in August 2018, just in time for Flow Festival. Over a thousand attendees played the game during the festival, revealing a number of issues. The following spring, we spent three months addressing these issues.

\textsuperscript{31} Sweetser and Wyeth, “GameFlow: a Model for Evaluating Player Enjoyment in Games,” 5–6.
and overhauling Global Warning. We completed the post-Flow update in June 2019. The three developmental stages are discussed in more detail below.

During the Alt+Ctrl workshop, the primary focus was exploration and discovery. Students brainstormed and discussed ideas, tinkered with various sensors and hardware controllers, and built working prototypes. Robin Baumgarten and Matti Niinimäki offered guidance, in addition to technical knowledge. At this stage, we experimented with simple and enjoyable interactions that utilized LED strips. We also began conceptualizing the gameplay and core mechanics. Hypotheses were driven by our design pillars and our understanding of the music festival setting. These are discussed in much more detail in the following chapter. Once the core mechanics were established, we made some simple sketches and a paper schematic of the physical design, followed up by the proof-of-concept prototype (Figure 9). Although the presentation was rough, with exposed circuits and loose wires, it demonstrated that a functional full version could be developed. It also provided our first opportunity for playtesting, and observing other students in the workshop confirmed our concept’s potential to be fun and engaging. During playtests, we also discovered our first issue. Although the position- and color-matching mechanics could be fun, color building was far too complex. Player consensus was almost unanimous, so it was discarded before moving on to the full version.

![Figure 9: First working prototype of Global Warning, developed during the Alt+Ctrl+Aalto workshop. The shield can be rotated around the ring by a rotary encoder, and its color can be changed by the red button. Randomly colored enemies travel down the strip and can be reflected by a matching color shield (Caleb Rugg).](image)

While producing the full version, our workload expanded considerably. The basic gameplay and mechanics had been decided, so the key focus areas shifted to software development, the overall user experience, hardware implementation, and construction of the arcade cabinet. During playtests with other students, we concentrated on balancing the game’s speed and difficulty, establishing clear feedback mechanisms and animations, adjusting controller sensitivity, and finding an optimal color scheme for the LED lights (there was often a tradeoff between brightness and differentiability). After eight weeks of development, the Flow Festival version of Global Warning was complete (Figures 10–12).
Exhibition at Flow Festival was a wild ride. Although the event was extremely chaotic to observe and document, sharing the game players was very satisfying. Many seemed to enjoy the game and expressed positive feedback. Hundreds of play sessions, however, also laid bare several major issues and design flaws. Chapter 5 discusses these problems in greater detail. It also offers some analysis and possible solutions, which were implemented in the next version of *Global Warning*, the post-Flow update. This is the current state of the game, and although substantial progress was made, lingering issues still remain.

**Figures 10, 11:** Developing the game for Flow Festival – constructing the handwheel controller box and programming gameplay in the Arduino development environment (Caleb Rugg).

**Figure 12:** The first full version of *Global Warning*, presented at Flow (Caleb Rugg).
Chapter 4

Designing the Game

This chapter details the design process of Global Warning. The first section introduces a classic arcade game genre and explores our decision to work within it. The second establishes a unifying theme, which influenced most major design decisions. The third and fourth sections elaborate on the development of gameplay and core mechanics. The chapter concludes by describing the design and construction of the arcade cabinet.

4.1 Building on a Classic Arcade Genre

The first three words of the preface in Salen and Zimmerman’s influential text, Rules of Play: Game Design Fundamentals, simply state “People love pong.” The authors then marvel at how a 30-year-old game – now almost 50 – still manages to delight crowds. After all, the game is quite simple. Players rotate a small knob to control their paddles, which are represented by two white lines on either side of screen, and volley a square ball back-and-forth. When one misses, the other scores a point. The first to 15 wins. The game is a very primitive abstraction of ping-pong, so why are people still playing it half a century later? The authors offer six key reasons to explain this phenomenon – the game is simple and approachable; every play session is unique; it is an elegant representation; it is social; it is fun; and it is “cool.”

For these reasons, Pong has become an arcade classic, and over the years it has inspired many sequels, clones, and variations, all of which contributed to the development of the paddle-and-ball game genre (Figure 13). Some well-known examples of games in this genre are Breakout, Quadrarpon, and a game that came pre-installed on everyone’s flip phone, Brick Breaker. Games such as these feature very similar core mechanics to Pong, often with only minor variations. Breakout and Brick Breaker, for example, are really just single-player versions of Pong. Instead of volleying back and forth with an opponent, it is the level structure itself that bounces the ball back to the player. The challenge is to destroy the entire structure by “breaking” each “brick” with the ball before missing too many times. The paddle is represented by a white line and is operated in the same manner as Pong. The only difference is it moves along the bottom of the screen rather than the side. Another small variation is the addition of power-ups, which can accelerate or enlarge the paddle or enhance the ball’s destructive power. Warlords is another arcade game that builds further on the genre by amalgamating the four-player version of Pong (Quadrarpon) and Breakout. Up to four players defend their brick castles from destruction by volleying a flaming ball back and forth. The last player with an intact structure wins the game.


33 Salen and Zimmerman, Rules of Play, 21–22.
Figure 13: Gameplay images of classic paddle-and-ball games *Pong*, *Quadrapong*, *Breakout*, and *Warlords* (from left to right, respectively). The paddle is represented by a vertical or horizontal line (shield icon in *Warlords*), and the ball is represented by a square (circular fireball in *Warlords*).

Considering the popularity of the genre, coupled with the historical success of games based on minor mechanic variations, we decided it was a worthwhile starting point for our game. Why reinvent the wheel when we could build upon a successful, established framework? The six reasons Salen and Zimmerman listed for *Pong*'s enduring success also aligned well with our key design objectives – Simple and Accessible, Exciting, Replayable, and Social. *Pong* is one of the best-known arcade games, and nearly everyone has played some form of *Brick Breaker*, so why not leverage that experience to develop a highly accessible, new game? Plainly put, we wanted to capitalize on the affordances of the genre to create something familiar but different. Hypothetically, this would lessen the cognitive load of learning a new game and lower the bar of entry. Working with well-established mechanics would also save valuable development time and allow us to focus on innovation rather than invention.
4.2 Finding a Unifying Theme

Identifying the genre in which we would work was a great first step. However, it was still difficult to begin the project. Although the design constraints were quite specific—a physical computing, LED-based paddle-and-ball game that utilizes alternative controllers—an initial brainstorming session generated an abundance of ideas and illustrated how many different directions we could proceed. Having too many ideas is a better problem than having none, but it is still a problem. The source of that problem, we realized, was that we had no methodology for evaluating those ideas and weighing them against each other. Besides intuition or personal preference, we lacked a framework for making informed design decisions. It was only after considering our intended message were we able to progress. In other words, we needed to establish our core theme.

In his influential book *The Art of Game Design*, gaming industry thought leader Jesse Schell explains the importance of establishing theme early on in the design process:

The sooner you have settled on a theme, the easier things will be for you, because you will have an easy method of deciding if something belongs in your game or not: If it reinforces the theme, it stays, but if it doesn’t, it goes.\(^{34}\)

In addition to focusing a design towards a common goal, he describes the primary benefit of basing one’s design around a single, unifying theme. It allows all elements of a game to reinforce each other, which is key to delivering a cohesive product.\(^{35}\) To emphasize the point, he offers a blunt, two-step process for strengthening any gameplay experience:

Step 1: Figure out what your theme is.
Step 2: Do everything in your power to reinforce that theme.\(^{36}\)

Screenwriting master Robert McKee agrees on theme, although he prefers the term “Controlling Idea” because it also implies function. Not only does it name a story’s central idea, it also shapes all of a writer’s strategic choices.\(^{37}\) It is quite intuitive actually. Once a core message is established, it becomes much easier to communicate it to others. Moreover, once a designer knows the feeling they want to convey, it becomes much easier to craft an experience, which is the essence of UX and game design.

Now that the necessity of establishing a theme is clear, how exactly does one go about it? Luckily, both writers offer further guidance. McKee defines a true controlling idea as “not a word but a sentence—one clear, coherent sentence that expresses a story’s irreducible meaning.”\(^{38}\) Schell believes that the best themes not only focus a design but also resonate deeply with players, adding that truly resonant themes are what elevate works from mere craft to art.\(^{39}\)

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38 McKee, *Story*, 115.
With these definitions in mind, we set out to establish our theme. Within their design guidelines, Flow Festival had provided the theme of “sustainability,” but according to McKee’s definition, it failed to meet the criteria of a controlling idea. It was more of a concept, providing direction for the development of a proper theme but not one itself. Statements like “Recycling is important” or “Don’t waste water” are improvements, but more specificity is required for it to help guide design decisions. They also lack the depth of a truly resonant theme. To find one, personal reflection is necessary and consideration of what one finds important. After some deliberation, a sentence formed that felt both personally meaningful and specific enough to be a controlling idea. Based on current global events, we also thought it might resonate well with a general audience. What we settled upon was “Climate change threatens our survival, and we must work together to confront it.” Once it was established, we gained a strong tool and clear methodology for decision-making. It clarified many aspects of the design, especially in the development of the overall gameplay and core mechanics, which will be discussed more thoroughly in the following section.

In summary, understanding exactly what we wanted to say and encapsulating it in one sentence was a fundamental early step and an important exercise in obtaining a clear design focus. It guided most of our design decisions going forward and established a methodology for evaluating whether new ideas added or detracted from a cohesive final product.

4.3 Defining Gameplay

Equipped with a theme, we could now begin defining the gameplay experience. According to Salen and Zimmerman in their seminal textbook *Rules of Play*, gameplay is defined as “the formalized interaction that occurs when players follow the rules of a game and experience its system through play.” Adams provides a more condensed definition in his *Fundamentals of Game Design*, describing gameplay as “the challenges and actions that entertain.” He offers more insight into the challenge-action relationship later on and describes why it is the essence of gameplay: a game presents challenges for a player to overcome while allowing actions for the player to overcome them. Examining games through the lens of interactive narrative, challenges are what create tension and dramatic conflict while actions provide opportunities for resolution. Synthesizing these two definitions, it was clear how to begin defining our gameplay. First, we needed to decide what kind of interactions we wanted to create. Then we needed to design a system of challenges and actions that facilitated those interactions.

4.3.1 A Twitch-Based Action Game

Based on the decision to work within the paddle-and-ball game genre, we knew our game would feature reflex and coordination challenges, both of which are hallmarks of action.

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games. Pong and Breakout both rely on these types of challenge, as players must react quickly to the ball's ever-changing position and move their paddle deftly to create a deflection. In fact, most golden age arcade games can be classified as action games. Pac-Man, Donkey Kong, Space Invaders, and pinball are all prime examples, with core gameplay that challenges players' reaction time and motor skill. Typically, action games are low on strategy and high on replay value, keeping players engaged with fast-paced gameplay, short and intense play sessions, and immediate feedback to their actions. Sub-genres of this style of game include first-person shooters, platformers, rhythm games like Guitar Hero and Dance Dance Revolution, and sports games. Although quite varied in appearance, they all require quick reflexes, strong hand-eye coordination, and split-second decision-making. The fastest action games are sometimes referred to as “twitch” or “twitch-based” games, implying the action is nearly automatic. Action games stand in stark contrast to turn-based strategy games. Most board games fit into this category and rarely feature reflex or coordination-centric challenges.

In addition to being in sync with the paddle-and-ball game genre, we also believed a twitch-based action game would fit well within a music festival setting. In their extensive research into the music festival experience, Moss and Henderson note that three of the main motivations for festival attendees are novelty, excitement, and escape. They are there to discover new and exciting experiences. It is also important to note that the primary draw of a music festival, of course, are the musical acts, rendering peripheral events like our game into more of a time-filling activity. Taking these aspects into consideration, twitch-based action gameplay checked all the boxes. Short, intense play sessions with fast action, flashing lights, and immediate feedback satisfied the urge for excitement while requiring only a small time commitment. The intensity of this style of gameplay also requires deep focus and concentration while testing newly acquired skills. These conditions can lead to experiences of flow, or full immersion in an activity. During a flow state, players lose sight of their surroundings and experience an altered sense of time. They also become less self-aware and less worried about everyday life. Such an experience would surely satisfy the need for escape.

For these reasons, we decided Global Warning would feature twitch-based action gameplay. The style emulated most golden age, classic arcade games, including those of the paddle-and-ball game genre. Short, intense play sessions with fast-paced action also aligned with festivalgoer motivations and our own design objectives.

4.3.2 Multiplayer Co-op

Another key motivational factor for festival attendees is socialization. They want to have fun with their friends, connect with new people, and share exciting experiences

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45 Adams, Action and Arcade Game Design, 1.
46 Jonathan Moss and Matthew Henderson, A phenomenological exploration of music festival experience, (Sheffield Hallam University, 2018), 30.
48 Ibid.
49 Moss and Henderson, Music Festival Experience, 30.
together. The same can be said about games. Social interaction is a huge part of what makes them fun, whether it is a contentious bout of Monopoly or a unified dungeon raid in an online role-playing game. Przybylski et al. reach a similar conclusion in their research into the motivational appeal of games, finding that it comes from satisfying certain psychological needs, one of which is relatedness, or a perceived connection to others. Addressing this need can lead to sustained engagement and even enhanced wellness. Simply put, games are more fun with others, and so are music festivals.

That made the decision of whether to make the game a single or multiplayer experience quite straightforward. In fact, in early ideation sessions we wondered just how many players we could actually include. Although it was exciting to devise games supporting three, four, or even more players, we eventually settled on two for practical reasons. Incorporating more added a great deal of complexity to the design and implementation. We also felt that the more players a game requires to get started, the less inclusive it becomes. For example, a group of three approaches a four-player game. Hypothetically, they could ask another festivalgoer to join them, but realistically, we figured many would walk away instead. On the other hand, if a group of three walks up to a two-player game, not only do they meet the minimum requirements, they can also rotate players and create three different two-player teams. With this dynamic in mind, we decided to set the group size requirement as low as possible for multiplayer play – two. We felt this would maximize the number of possible players while simplifying game design and fulfilling the relatedness needs of players and festivalgoers.

Examining different multiplayer arcade games, two basic types begin to emerge – competitive and cooperative. In competitive games, players act in opposition to each other, while in cooperative games, players work together towards a shared goal. Some games feature both, offering a choice between play modes or in the form of team-versus-team. Implementing both would complicate the design process substantially, so we had to decide whether players should compete head-to-head or work together. Luckily, our unifying theme offered guidance. The message we wanted to impart was that climate change is an existential threat we must face together, which implies cooperation towards a common goal, or in this case, against a common enemy. Competitive gameplay did not make sense thematically.

We also felt that a cooperative game would resonate more with festivalgoer motivations. Although competitive games can be highly engaging and create memorable shared experiences, cooperation mechanics have a stronger impact on players' sense of relatedness. Cooperation facilitates interpersonal trust development better than competition, and players invest more effort into a game when they share a common goal. As socialization and connectedness are key motivators for festival attendees, cooperation

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51 Przybylski, Rigby, and Ryan, “Motivational Model,” 165.


mechanics appeared to offer more value.

Multiplayer co-op mechanics would also differentiate *Global Warning* from other arcade titles within the paddle-and-ball game genre. The only variation of *Pong* that utilizes collaboration is *Pong Doubles*, but that is just *Pong* with two-player teams and is still mainly competitive. Brick-breaking games like *Breakout* and *Arkanoid* are single-player experiences, although two players can alternate turns and compete for score. *Warlords* and *Quadrapong* can support up to four players, but each one plays independently. We wanted to innovate on a classic genre. Implementing multiplayer cooperative mechanics seemed like our first opportunity to do so.

In summary, we decided that *Global Warning* would feature multiplayer cooperative gameplay because it aligned well with our theme and the intrinsic motivations of festival attendees. It would also differentiate us within the paddle-and-ball game genre. A two-player game made the most sense due to the complexity of incorporating more. It is also the lowest possible amount for local multiplayer play and enables any-sized group to enjoy the game.

### 4.3.3 Asymmetric Interdependence

Another important consideration when designing *Global Warning* was the heterogeneous mix of festivalgoers. Flow Festival prides itself on its eclectic program, and upon examination of the 2018 headlining acts, one would certainly agree: US rapper Kendrick Lamar, English rock band Arctic Monkeys, and Swedish pop star Lykke Li. Various singer-songwriters, DJs, hardcore bands, jazz ensembles, and more played on a collection of nearby stages. In addition to musical performances, Flow Festival 2018 featured a multi-disciplinary art program, food from over 40 different restaurants, and a selection of films. They also hosted an event called Family Sunday, where parents could bring their kids for face painting, skateboarding and graffiti workshops, a child-friendly disco, and, of course, games. Festival organizers expected over 80,000 people to attend over the weekend, and with such an eclectic program, we anticipated the crowd to be similarly diverse.

With such a diverse crowd come players of all ages with vast differences in skill, experience, and interest in games. We knew that designing a game enjoyed by all was likely impossible, but our primary goal was to engage as large an audience as possible. Thus, we chose to employ asymmetric gameplay within *Global Warning*. In asymmetric games, players may possess different abilities, start in different positions, strive toward different win conditions, or even operate under different rule sets entirely. This lies in stark contrast to games of symmetry like chess, *Pong*, or professional sports, where the initial conditions, actions allowed, and victory requirements are the same for all players. If utilized correctly, we believed asymmetric gameplay could compensate for differently skilled players by

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54 Flow Festival, *Flow Festival takes place this weekend in Helsinki’s Suvilahti*, 7 August 2018.
55 Ibid.
56 Ibid.
57 Flow Festival, *Flow Festival takes place this weekend in Helsinki’s Suvilahti*, 7 August 2018.
58 Ibid.
60 Ibid.
providing distinct roles. By offering multiple ways to interact with the game, we also expected asymmetric roles to increase replayability. Furthermore, by making those roles both complementary and interdependent, we could bolster *Global Warning*’s cooperative gameplay and reinforce our theme.

The idea to include asymmetric gameplay in *Global Warning* was precipitated by playing two games in particular: Asteroid Base’s *Lovers in a Dangerous Spacetime*, which was a new release, and Arrowhead Studios’ *Gauntlet: Slayer Edition*, which is a modern update to the 1985 arcade game *Gauntlet*. Both illustrated how engaging asymmetric roles within a team could be, and they accomplished it in different ways.

In *Spacetime*, up to four players pilot a giant spaceship, working together to operate different battle stations within it (Figure 14). There are turrets, lasers, shields, and thrusters, and players must frequently change positions and swap roles depending on the situation. Players must rely on each other to successfully navigate their ship through deep space. Similarly, in *Gauntlet*, up to four players select a character – Warrior, Valkyrie, Wizard, Elf, or Necromancer – and venture into a dungeon together to fight monsters and collect treasure. Each character has different abilities, weapons, and vulnerabilities that force players to work together. For example, the Warrior has high health and powerful close-combat abilities, while the Elf has low health but high speed and ranged attacks. While the Warrior jumps into a melee and endures the punishment of close-quarters combat, the Elf lays cover fire and snipes high-priority targets. Their complementary attributes make them an effective team.

**Figure 14:** Gameplay image from *Lover in a Dangerous Spacetime*. Players share control of a giant spaceship, operating battle stations with different capabilities. Survival depends on successful cooperation.

Both games illustrate different ways to incorporate asymmetric mechanics. *Gauntlet* provides complementary abilities that encourage cooperation through synergy, while *Lovers in a Dangerous Spacetime* necessitates it through interdependent roles. The spaceship is a
shared body that players operate together. While one steers the ship, another shoots the cannon, and a third operates the shield. It is only through teamwork that a functional whole is created – a ship capable of moving, attacking, and defending. For this reason, asymmetric interdependent gameplay offered more value to *Global Warning*. It would force cooperation and underscore our theme that climate change is a problem we must face together. As players and as a planet, we are dependent upon each other for survival.

Asymmetric roles can also simplify a gaming experience. By giving each player a specific duty, their role within the team is clarified. For example, if a player has chosen to be a Cleric in *Dungeons & Dragons*, then they know their primary function is to support their allies by using divine magic for healing and inspiration.\(^61\) Similarly, if a Fighter is chosen, then the player knows they will be on the front lines of battle, well-versed in combat styles, weapons, and armor.\(^62\) If characters possessed the attributes of both, player roles within the team would be unclear. The need for cooperation would also be negatively impacted. If both have the ability to fight and heal, then there is little incentive to rely on each other. Developing asymmetric, complementary abilities would ensure cooperation and guide players toward specific roles within the team. We also hoped that this would simplify the game and shorten the learning curve for new players.

We also believed that asymmetrical roles would improve the replayability of *Global Warning*, another key design objective. Multiple ways to experience the game would incentivize players to swap positions and try again. In the process, they discover which role aligns better with their skills and preferences. In this way, asymmetric gameplay provides multiple games in one. It also allows players to embrace their differences and find their niche within the team.

Another important deciding factor was that upon examination of arcade titles within the paddle-and-ball genre, no examples were found that featured asymmetric gameplay. On the contrary, symmetry was heavily emphasized. In each game, players faced the same challenges, performed the same actions, and operated the same controls. It made sense when considering the competitive nature of these games. Symmetric design ensures fairness, and fairness is an important element in competitive games, especially sports, and *Pong* is modeled on the sport of ping-pong, after all. All previously mentioned titles of the genre – *Pong Doubles, Quadrabong, Warlords, Breakout*, and *Arkanoid* – are similarly symmetric. The issue of perfect fairness, however, becomes less critical when players no longer act in opposition. In fact, having players on the same team with asymmetric abilities can create many more gameplay possibilities, as discussed above. Interestingly, by choosing cooperative play for *Global Warning*, we discovered another way to innovate on the paddle-and-ball genre: implementing asymmetric interdependent gameplay.

4.4 Developing Mechanics

4.4.1 Two-Dimensional Deflection and a Shared Avatar

Deflection is the defining mechanic of all paddle-and-ball games. In *Pong* and any of its variants, if players fail to deflect an incoming ball, then their opponents score a point. In *Breakout* and other brick-breaking titles, if a player is unable to deflect the ball back at the level architecture, then they lose a life. In *Warlords*, players must protect their own structures by deflecting fireballs at their opponents’ castles. The winner is the last man standing with an intact structure. In order for *Global Warning* to be considered part of the paddle-and-ball game genre, its core mechanic and primary player challenge needed to be deflection.

Historically, however, deflection has been a one-dimensional mechanic based solely on position. Each player operated their own paddle, which was controlled by a rotary knob. Separate paddles with identical abilities and controls provide perfect symmetry, but we wanted to create an asymmetric experience. We also wanted the player roles to be more interdependent and closely coupled with the intention to facilitate and strengthen cooperation. Thus, our key design challenge was to adapt this one-dimensional, symmetric mechanic into an asymmetric, interdependent one. *Lovers in a Dangerous Spacetime* inspired us to consider a shared avatar concept, accomplishing our goal by having both players "occupy" the same paddle but control different aspects.

"Avatar" derives from a Sanskrit word referring to a god that has magically taken physical form on earth, and in games it means the personified representation of the player within the game world. In a board game, it is the piece moved by the player – the racecar or top hat in *Monopoly*, for example. In a video game, it is the digital character a player controls – Mario, the spaceship in *Galaga*, Pac-man, etc. In paddle-and-ball games, the paddle is the avatar. When a player interacts with their controller, the paddle moves. The interaction is clear and simple, and the paddle becomes an extension of the player within the game. A shared avatar, however, is one in which multiple players inhabit the same avatar, like the spaceship in *Lovers* where players operate different stations within it to create a functional whole. Shared avatars can encourage cooperative thinking by delivering a common body, shared goals, and interdependent roles. A shared avatar would be a major departure from other games in the paddle-and-ball game genre, but it was another opportunity to innovate and differentiate *Global Warning*. The key would be finding a way to add another layer to the interaction but keep the simplicity.

Position matching was the sole criteria for deflection in previous paddle-and-ball arcade games, so there needed to be another dimension to incorporate a second player. Knowing that LED lights would be used to visualize gameplay, color matching emerged as the obvious solution. If brightness is not considered, then position and color are the two data points that govern LEDs, so it made sense to separate control of these variables among the

63 Schell, *Art of Game Design*, 348.
players. This would create asymmetric interdependent roles within the shared paddle avatar (visualized by LEDs). Simply put, while one player could move the paddle, the other could change its color. With a color-changing ball, successful deflection would depend on the paddle matching both its color and position. Players have to rely on one another and work together to achieve their mutual goal. In this way, a shared avatar also reinforced our theme of global preservation. If earth could be considered a shared avatar, perhaps humans would align their behaviors to confront global warming.

4.4.2 Random Enemies in an Endless Level

Levels are a key component of most video games. They provide a sense of progression and accomplishment, as well as an ebb and flow to the pace of gameplay. Breaks between levels allow players to rest, admire their progress, and evaluate their strategy before the difficulty escalates. Most classic arcade games have distinct levels. Breakout has two, Donkey Kong has four, Mario Bros. has 35, and Galaga and Pac-Man both have 255.

Endless runners, however, are a popular type of mobile game that lacks distinct levels. Instead, they feature a seamless escalation of difficulty inside one never-ending level. Because they provide no breaks, endless runners can heighten tension and feel more fast-paced. We decided to emulate this style because it aligned with our design goal of providing quick and exciting play sessions. This objective was set based on the assumption that festivalgoers would have short time windows between musical performances to focus on other attractions. An infinite level would also be a unique feature compared to other arcade games. Tetris was a notable counterexample that proved an endless level could be a viable choice for Global Warning.66 And Crossy Road was an example of a successful adaptation of a classic arcade concept into an endless runner. The game is essentially Frogger with a procedurally generated, infinite level.

With a never-ending level, we needed a way to generate content and add variation. To solve this issue, we implemented an algorithm that spawned randomly colored enemies at random positions, i.e., the two variables that produce a successful deflection. Together, these variables ensure that no two games of Global Warning are the same, a decision we hoped would increase the game’s replayability and avoid frustration caused by repetition. We also created variables for enemy speed and spawn rate. By increasing and decreasing these variables at certain times, we could create a similar ebb and flow of gameplay found in games with distinct levels.

4.5 Constructing the Cabinet

The primary objective of the Alt+Ctrl+Aalto workshop was to develop experimental hardware games. Therefore, we decided very early on in the design process not to use a standard digital screen to visualize gameplay – a strong departure from typical arcade video games. Instead, individually addressable LEDs serve as the game’s basic visual element.

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NeoPixel was the specific brand chosen. In addition to being super bright and colorful, they interface easily with different microcontrollers, have extensive documentation online, are affordable, and come in various configurations. For these reasons, NeoPixels have become very popular in the maker community. Robin’s Line Wobbler, for example, uses a several meter-long strip of them as its experimental display. His follow-up project Quantum Garden utilizes Neopixels as well, but in a multitude of ring configurations rather than one long strip. His experience and overall depth of knowledge, especially in programming animations, also influenced our decision to use NeoPixels for Global Warning.

Once the game’s basic visual unit (or pixel) was established, next was designing the display. This was an interesting challenge because pixels needed to be arranged in a way that could visualize all possible game events. This is not a concern with standard digital screens, as pixels come pre-arranged in rectangular grids of different aspect ratios, and everything happens within that defined playspace. This stage of the process felt more like designing a board game than designing an arcade game, laying down paths for the gameplay to follow. A stronger comparison might be to handheld LCD games of the 1980s and 90s, like Nintendo’s Game & Watch series or titles by Tiger Electronics. In these games, graphic elements are fixed in place, so every possible state and location of game objects is preset. Movement is then simulated by flashing objects sequentially between states. Graphics are transparent when not in use, but the entire array can be seen when a game is reset (Figure 15).

![Figure 15: LCD game Fire from Nintendo’s Game & Watch series. Image on the left shows all graphic elements and every possible state while image on right shows actual gameplay. (Super Mario Wiki, “Fire – Game & Watch,” accessed 6 April 2020, https://www.mariowiki.com/Fire_(Game_%26_Watch)).](image)

After experimenting with different configurations for the game board, eventually we settled on a wheel-and-spokes design: a pulsing light in the center to represent Earth, a ring around it to represent the shield, and eight radial paths down which enemies would travel. We settled on this arrangement because it was simple, straightforward, and provided ample variation in gameplay. The shape also allowed us to take advantage of the format NeoPixels that come in – long strips and fixed-size rings. Once the overall shape was determined, then we could decide the resolution. This was a delicate balance between physical space, available memory, and smoothness of animation. NeoPixels come in strips of 30, 60, and 144 LEDs per meter. We opted for the latter because more tightly packed pixels create smoother animations. NeoPixels also come in different-sized fixed rings of 12, 16, 24, and
60 LEDs. The 24-pixel ring made the most sense for visualizing the shield because it had a similar density to the 144 strip. It also fit well within the game board, aligning with one of the strips on every third pixel. In all, *Global Warning* uses 284 pixels to visualize its gameplay. There are 32 coming down each of the eight enemy lanes, 24 around the central shield ring, and four in the middle to represent Earth.

Another objective of the Alt+Ctrl+Aalto workshop was to explore non-traditional forms of input and incorporate unique hardware controllers into our game. This essentially meant no keyboards, joysticks, or gamepads – standard interface architecture for video games. When selecting controllers for *Global Warning*, our key focus was intuitiveness. Controllers needed to be simple and straightforward with one inherent use. The use needed to be coherent with the game board’s configuration, and in order to provide an asymmetric experience, two distinct controllers were needed. After experimenting with different mechanisms and keeping these concerns in mind, eventually we settled on an industrial hand wheel (to rotate the shield around the center ring) and a four-way switch (to change the shield four different colors). These controllers, which are typically found in industrial machinery, create memorable interactions for the player and bring a certain physicality to the game. With the four-way switch, players feel the satisfying crunch of grinding of gears, while the hand wheel glides smoothly in rotation.

Once the controllers and game board were set, it was time to construct the main body of the arcade cabinet. For inspiration, we looked to cocktail cabinets of the 1970s and 80s. The key feature of this style of cabinet is its upward facing display, which also doubles as a tabletop (Figure 16). Tempered glass above the screen gives players a nice spot to set drinks. This made them popular in pubs and bars during the Golden Age – some even had ashtrays – but they have mostly disappeared since then. This style felt well-suited for the festival environment, as many would be eating or drinking something. It also felt more communal than traditional upright cabinets, as players and spectators stand around the game with bodies turned towards each other rather than shoulder to shoulder. Nostalgia played a part as well, as I had fond memories of playing on these rare, mysterious machines as a kid. In adherence to the style, we installed a cup holder for each player next to their controller. An interesting deviation, however, is how we placed the controllers. Instead of placing them on opposite sides in a head-to-head formation, which is typical for cocktail cabinets, controllers were placed next to each other in a non-oppositional way. This was to help highlight the cooperative gameplay.

To match the exhibition’s physical setting, which was a large, open-air, wood pavilion, we constructed the cabinet out of thick birch plywood. This gave the game a more tactile, organic, and handmade feel. Its wooden construction also harkened back to coin-operated amusements of the late 19th and early 20th century. Combining this with bright neon LEDs, we hoped to create an eye-catching anachronism. To enhance the effect even further, we placed a thin piece of wooden veneer (0.3mm in thickness) over the lights to act as diffusion and obscure the machine’s inner workings. This simple choice brought “wow factor” to our game by creating the illusion that light emanates from within the wood itself (Figure 17). We also weatherproofed the game by coating the wood with varnish and sealing the edges with silicone, as *Global Warning* would be exposed to the elements for the duration of Flow.

Figure 17: Series illustrating the visual effect created by wood veneer. (Caleb Rugg)
Chapter 5

Observation, Analysis, and Improvements

This chapter begins with a description of the game’s installation at Flow Festival. It then recounts observations made during hundreds of play sessions with festivalgoers. After some analysis, these observations inform improvements that are implemented into a second iteration of the game.

5.1 Observations from Flow Festival

On 2 August 2018, one week before Flow Festival, installation began on-site at Suvilahti. A total of five projects from the workshop were to be shown: three games and two playful experiences. They were set up inside a large wooden pavilion called the Aika-lava, or Time Stage, which was designed by architecture students from Aalto University. The impressive indoor-outdoor structure had riblike walls that let in sunlight and created shifting shadows throughout the day. Our workshop’s projects were a natural fit for the Aika-lava, sharing the same wooden construction and minimal design, establishing a strong visual theme. The Aika-lava was prominently located, near the entrance that opened up to the main festival grounds, making it the first structure that many festivalgoers would see.

Once the projects were set up, students organized a shift schedule for the duration of the festival. This ensured that two or three people were always on hand to answer questions, explain how to play the games, and deal with technical issues that might arise (Figure 19). The Global Warning team was present for about 15 hours, and during this time we observed hundreds of players interacting with the game. We also had many conversations with festivalgoers who gave valuable feedback. Several students also shared observations and feedback they received while on shift. The rest of this section outlines our key learnings from the exhibition at Flow Festival. First, it examines where the game succeeded — what worked, which hypotheses were true, what positively surprised us, etc. Then it explores what failed.

5.1.1 Positive Findings

Since this was the first time *Global Warning* was played by a general audience, one of our proudest accomplishments was that the game did not break. Its physical design and electronics withstood hundreds, if not thousands, and not only remained intact, but continued to perfectly function. It even survived two thunderstorms, leading to magical moments of players huddled over the game, the lights warping and refracting in rain pooled on the display. Obviously, this was a welcome surprise for us, as we had mentally prepared ourselves for the game to be in shambles by the end, or at least to require substantial refurbishing. But besides a bit of grease on the handles and superficial wear-and-tear, the game held up. We were glad to see that the hard work and attention to detail put into construction led to better than expected results. Although this was a student project, we felt that we had delivered a professional product.

In addition to hardiness and operability, another successful feature of the physical design was its aesthetics. As we had hoped, players were enthralled by our lights and animations. At night the effects were even more pronounced and drew people in from a distance. Curious crowds would gather around the game and watch others play. Every once in a while, someone would stop and stare intensely for several minutes, seeming to experience their own personal rave. Fascination with the lights also led to some unexpected results in gameplay, as some players would purposely fall in order to see the game over animation. Most people were curious about the display. They would look down at the game, wave their hand over the lights, then look up to the ceiling, searching for a hidden projector. When they could not find one, they barraged us with questions. Almost no one guessed that the lights were shining through a thin layer of wooden veneer. My favorite explanation was that it was “black magic.”

Players also loved the tactile quality of the wooden construction and mechanical controllers. Young children seemed to enjoy them the most. They would spin the wheel around as fast as they could and wiggle the joystick back and forth. They had no understanding of the game but still had fun. Adults frequently commented on the cupholders, finding their inclusion in the design to be amusing and thoughtful.

Our observations also confirmed several of our gameplay hypotheses. Play sessions were short and intense, requiring deep focus from players. Many called it hectic, thrilling, and exciting, while others called it stressful. Kids would play and then run off to tell friends and family, often returning with them to play together. As we had hoped, general audiences understood the game easily and were able to start playing quickly (Table 2, row 1). People learned by watching others play or after short explanations from us. We interacted with many people who did not speak English, and found the game was simple enough to teach without a shared language. By pointing at the shield avatar and demonstrating what each controller's function, we could normally get a game started quickly.

Most players seemed excited by the cooperative mechanics. They enjoyed that it was a team effort against the game, rather than player versus player. This resulted in frequent communication between players, both for planning strategy and sharing knowledge. Players commonly swapped roles to become a more effective team, with skillful players
switching to the joystick position, which was universally regarded as more challenging (Table 2, Row 2). Likewise, lesser skilled players, or those less interested in challenge, gravitated towards the wheel (Table 2, Row 3). This proved our hypothesis that asymmetric controls encouraged play across skill levels, leading to nice moments of very different people playing together. The asymmetric controls also added to the game’s replayability, as players often changed positions and tried again with the other controller.

Overall, seeing so many people play the game confirmed our feeling that we had created a fun, engaging game. We found that the game appealed to players with a variety of ages, skills, and backgrounds. It also turned out that with its quick play sessions, sturdy cabinet and colorful lights, our game was well-suited for the music festival environment.

5.1.2 Negative Findings

During the exhibition at Flow Festival, we also discovered major issues with Global Warning. The biggest was that the first-time user experience was unclear without guidance. Although instruction plaques were affixed to the machine by each controller, barely anyone read them. They were also overly simple and failed to communicate clearly what to do and how to get started. Nearly all first-time players needed explanation from us or to watch others play first to get started. Without one or the other, they would fidget with the controllers, admire the lights, then leave in confusion. Very few were able to simply walk up and play. The game’s cooperative aspect was especially unclear to first-time players without instruction or demonstration. They did not make the connection that they needed to work together. After watching people’s initial interactions with the game, especially how they approached it and stood around it, we also realized that the start button was quite difficult to find.

In addition to the issues affecting first-time users, several other aspects of the game were unclear. For example, because the number of lives players had was not communicated in a direct way, players did not understand how many times they could fail before a game over. Player lives were visualized by the center light, which would flash faster and faster as lives depleted, and turn red when only one remained. Players often recognized that the flashing red light meant they were close to game over, but they were uncertain how many lives they had started with or exactly how many they currently had. It was also unclear to some players whether they were succeeding or not. Overall, players needed clearer feedback for their actions and better communication about the state of play. Many players mentioned sound effects as a possible solution.

Another common question that players had was “How do we win?” The honest answer was that they couldn’t – the game continued until they lost – and for some players that didn’t feel fair. They felt they needed some way to win. Some players also expressed the need for more complexity. The game was fun to play a few times, but after that it became repetitive. A larger variety of challenges would make the game more interesting. Finally, many commented that the game was fun but too hard. Observing people play, it was evident the difficulty curve escalated too steeply and required smoothing.
In summary, while the game was well-received by many players, there was significant room for improvement. Players had trouble learning the game without instruction, a hurdle that would become significant were the game to be shown in a less-crowded venue. Players also struggled with how to start the game, as well as how to win or how close they were to losing. Confronting these problems provided an opportunity to fix them, which is the topic of the next section.

5.2 Analysis

Showcasing at Flow Festival was essentially one massive playtest. In a period of three days, we watched hundreds play the game, and got feedback from a wide demographic of players. Many observations and feedback were aligned, but some players offered contradictory suggestions. Once the festival was over, we had space to analyze the totality of feedback and extract the most meaningful lessons. Wanting our observations to be as empirical as possible, we tried not to lean too heavily on intuition, but to rely on what we saw or heard. We then used design heuristics to translate these observations into well-defined problems.

These heuristics helped condense the results from hundreds of playtests into a few key problem areas. We then analyzed these problems to decide which were most important. Of those that were most important, we further narrowed down to those that were solvable with our time and resources. Below we have synthesized our observations from Flow Festival into 15 points and paired them with a corresponding heuristic from Sweetser and Wyeth’s GameFlow model (Table 2). As contrast, we have also provided several examples in which the game was a success and included the heuristic that explains that success. Occasionally, one problem area is covered by two heuristics, or vice versa, and is listed twice. In the section that follows, I will reference this table as we discuss the ways in which we corrected those problems.
<table>
<thead>
<tr>
<th>Observation</th>
<th>GameFlow Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Success: When instructed, players learned the controls and mechanics quickly</td>
<td>Player Skills – Game interfaces and mechanics should be easy to learn and use</td>
</tr>
<tr>
<td>2 Success: players coordinated as a team, switched controllers, and often taught others how to play</td>
<td>Social Interaction – Games should support social interaction between players</td>
</tr>
<tr>
<td>3 Success: Less-skilled players typically gravitated towards the position-changing role, while more skilled players assumed color-changing duties.</td>
<td>Challenge – Games should provide different levels of challenge for different players</td>
</tr>
<tr>
<td>4 Problem: Players could not easily ascertain their current health.</td>
<td>Feedback – Players should always know their status or score</td>
</tr>
<tr>
<td>5 Problem: Players could not get started without help due to poorly placed start button.</td>
<td>Player Skills – Players should be able to start playing the game without reading the manual</td>
</tr>
<tr>
<td>6 Problem: Lack of enemy variation meant the game did not provide new challenges.</td>
<td>Challenge – Games should provide new challenges at an appropriate pace</td>
</tr>
<tr>
<td>7 Problem: The game offered players no significant choice in strategy.</td>
<td>Control – Players should feel a sense of control over the actions that they take and the strategies that they use</td>
</tr>
<tr>
<td>8 Problem: Players were unsure how to win. They were not given a clear goal.</td>
<td>Clear Goals – Overriding goals should be clear and presented early</td>
</tr>
<tr>
<td>9 Problem: Players were unsure how to win. They were not given a clear goal.</td>
<td>Clear Goals – Players should receive feedback on progress toward their goals</td>
</tr>
<tr>
<td>10 Problem: No scoring system meant players were not rewarded for playing well.</td>
<td>Player Skills – Players should be rewarded appropriately for their effort and skill development.</td>
</tr>
<tr>
<td>11 Problem: No leaderboard / scoring system meant players could not compete against each other.</td>
<td>Social Interaction – Games should support competition and cooperation between players</td>
</tr>
<tr>
<td>12 Problem: The game did not provide enough depth for highly skilled players.</td>
<td>Challenge – Games should provide different levels of challenge for different players</td>
</tr>
<tr>
<td>13 Problem: The game provided only visual feedback.</td>
<td>Concentration – Games should provide a lot of stimuli from different sources</td>
</tr>
<tr>
<td>14 Problem: The game provided only visual feedback.</td>
<td>Feedback – Players should receive immediate feedback on their actions</td>
</tr>
<tr>
<td>15 Problem: Lack of music was a missed opportunity for immersing players in the game's mood and universe.</td>
<td>Immersion – Players should feel emotionally and viscerally involved in the game</td>
</tr>
</tbody>
</table>

**Table 2:** Analysis table connecting observations from Flow Festival to related heuristics from Sweetser and Wyeth’s GameFlow Model.66

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5.3 Second Iteration Improvements

After showcasing *Global Warning* at Flow Festival, we spent three months iterating on its design to fix the issues we had discovered. In this section we draw from the above analysis section, expanding on problems and detailing the designs we implemented to fix them. Subsection 5.3.1 deals with improving usability and the overall player experience. Subsection 5.3.2 details ways in which we deepened the game by adding new abilities, variety, and a competitive dimension. Subsection 5.3.3 explores the way in which sound and music were implemented to enhance both mood and gameplay. Subsection 5.3.4 discusses gameplay analytics which can be used to aid further iteration. The final subsection explores plans for future improvements.

5.3.1 Improving Usability and the Player Experience

Two major usability issues presented themselves at Flow. The first dealt with starting the game: because our start button was in a difficult to find location, new players could not easily figure out how to begin playing. The second dealt with playing the actual game: because of a lack of proper feedback, players could not easily deduce their current health (Table 2, Row 4). The key to addressing these issues was better communication. To make starting the game easier, we installed an illuminated start button that would draw players' attention. To convey health, we implemented alphanumeric panels which clearly displayed health as a number.

Traditional arcade games often feature flashing letters telling players to “INSERT COIN(S)” or “PUSH START TO PLAY.” *Global Warning* did not have that feature and assumed players would know how to get started (Table 2, Row 5). But because the start button lacked clear messaging and was placed in an unintuitive location, first-time players struggled to get started without hands-on guidance – a requirement that was extremely impractical. By installing dynamic LED displays, we could direct players to the start button, making our presence unnecessary.

We then used those same LED displays to better inform players of their state. In a game, relevant data like score and health is always in flux. In *Global Warning*'s first iteration, health was conveyed abstractly: the faster the center light representing Earth pulsed, the more damage the player had taken. This had several problems. First, this connection between flashing Earth and player health was never explicitly stated. Second, conveying health in this manner was abstract and open to interpretation. For instance, did flashing rapidly mean three hits until defeat or one? Thus, players were unable to grasp their in-game status. By using LED displays to convey this information more plainly, gameplay was clarified considerably.

The key challenge in making these changes was retrofitting them into an existing game with limited physical space. In a digital game, user interfaces can be easily adjusted, but with a tangible one, our options were limited. We used modular, 14-segment LED displays that interfaced well with the microcontrollers we were using. Then we assembled small wooden boxes to house the displays and hide their circuitry. To give each player their
own messaging system we affixed one to each player's controller box. We also replaced the easy-to-miss, black start button with a flashing blue one, making it more visible to players as they approached the machine.

After watching hundreds of people play the game, it became clear that difficulty progression was too quick for first-time players. Even the tutorial was challenging, and players who struggled there found the rest of the game even more confusing and difficult. We were overloading players at the beginning, requiring them to simultaneously learn new game mechanics and operate unfamiliar controllers. This created a stressful and confusing experience for first-time players and caused many to give up. To address this, we slowed down the game's progression, giving players more time to learn the fundamentals. However, not all players would be first-time players. We needed to consider the experience of returning players who did not need an extended tutorial. These players already understood the game and wanted to jump right into the challenge. To reconcile this, we made the initial enemies that players encounter move slower and decreased the amount of deflections needed for players to advance out of tutorial mode. This allowed returning players to demonstrate competence quickly, while giving beginners additional time to learn within a slower environment.

Leading up to Flow Festival, playtest sessions with first-time users were rarely performed. Instead, the majority of testers were students already familiar with the game. This helped create a suitable difficulty curve for returning players, but is likely the reason Global Warning had problems with its first-time user experience. It also explains our failure to recognize potential issues with the Start button.

In summary, observing hundreds of playtests allowed us a valuable opportunity to improve our game. By seeing where players consistently struggled or complained, we were able to design fixes to address those problems. Some of these problems, while obvious in hindsight, were difficult to predict without witnessing players in a real world environment. Thankfully, we had ample testers and the time and resources to iterate upon the game.

5.3.2 Adding Depth

In addition to smoothing out the on-boarding experience for new players, we wanted to bring depth to the game for skilled players. By adding features, we hoped to create a more engaging experience and increase the game's replayability. Some features had already been planned leading up to Flow, but it was important to test the game's core mechanics before introducing them. After the festival, it was clear that more complexity should be added, as most players understood the game easily, and many could quickly master its simple mechanics. Some excited players even offered their own suggestions for how we could enhance the game, which was a clear indication that more depth was needed. After brainstorming, we had many exciting ideas for new features and chose three to implement—a new enemy type, asymmetric power-ups, and a scoring system. We settled on those because each served a different gameplay function that could also increase engagement—presenting a challenge, granting a special ability, and establishing an objective, respectively.
By introducing a new enemy type, we hoped to bring variety to the game and create new challenges (Table 2, Row 6). A new challenge to overcome was an additional chance for the player to experience competence, a key driver for intrinsic motivation.\textsuperscript{67} What we came up with was a color-changing enemy that switched back and forth between two colors at timed intervals. As the game progressed, these intervals would shorten, making deflection more difficult. These color-changing enemies required pattern recognition and added a rhythm-based challenge to the game. Before their introduction, the only way for us to affect difficulty was by changing enemy speed, but we now had additional dimensions: we could increase the ratio of color-changing enemies to regular enemies, increase the rate they changed color, and even have them alternate between more than two colors. Having options to shape the difficulty curve meant more control over the player experience, resulting in an overall more engaging game.

Power-ups are special items that grant players powerful, temporary abilities. By incorporating them, we hoped to bring a strategic element to the game and provide players with more choice (Table 2, Row 7). More choice could create a stronger sense of autonomy and enhance intrinsic motivation.\textsuperscript{68} Likewise, strategy could contribute to a player’s sense of mastery. One obvious design decision was to give players choice over when to use power-ups. They could be activated immediately or saved for a more tactical moment. We also gave players choice by having power-ups that provide asymmetric, complementary abilities. Players could activate power-ups individually or in unison, depending on the gameplay situation. It also created a new opportunity for players to collaborate, reinforcing our theme of interdependence.

Power-ups often grant temporary invincibility – the Super Star in the \textit{Mario} series, the Power Pellet in \textit{Pac-Man}, etc. – and we wanted to extend that to \textit{Global Warning}. With asymmetric abilities, however, invincibility was different for each player. For the position-moving player it meant always being in the right position for deflection. For the color-changing player, it meant always being the right color. We devised these power-ups as “Full Shield” and “Rainbow Shield,” respectively. When “Full Shield” is activated, the shield extends into every position, creating a circle around the center. The color, however, is not affected. When “Rainbow Shield” is activated, the shield rapidly cycles through all four colors. The position, however, remains unaffected. Only when activated together do these asymmetric power-ups create invincibility for both players. Otherwise, it only affects the player who used the power-up. By allowing more interesting choices, we hoped power-ups would create a deeper, more engaging experience.

The first iteration of \textit{Global Warning} had no scoring system, not even one that was tracked in the background, and we decided to implement one for the following reasons: First, we wanted to provide additional real-time feedback to players and reward them for successful play. This would help guide the player experience, showing them what to do and what not to do. We also wanted to establish a simple metagame to increase replayability. Many players found our game engaging, but needed a reason to come back. Having a score/leaderboard was an easy way to do that, allowing players to leave their mark on the

\textsuperscript{67} Przybylski, Rigby, and Ryan, “Motivational Model,” 156.
\textsuperscript{68} Ibid.
game and compete against friends. Before a leaderboard, this competitive aspect was absent from our game.

Finally, a lack of score made players frequently ask "how do I win?" They did not feel there was a clear goal or objective, and simply not dying was not enough (Table 2, Row 8). To solve this we had to direct them to obtain as high a score as possible (Table 2, Row 9). Since their goal was to achieve as high a score as possible, that meant we had to be clear about giving them with points in exchange for playing well (Table 2, Row 10). This meant adding bonuses for skillful play and allowing players who earned a high score to enter their initials on the leaderboard (Table 2, Row 11). Because of a shared avatar creating interdependence, our game already encouraged cooperation, but it took the addition of a high score board to create a competitive metagame.

Besides assisting with the above heuristics, adding score and a leaderboard provided many other benefits. Score helped players learn the game. Every time a player earned points, it was feedback that they were doing something right. So to guide play in the direction of maximum enjoyment and engagement, we created the following scoring scheme: A simple deflection (matching both the paddle's position and color to the incoming ball) resulted in a base of 300 points. Skill-based multipliers were then added, which were multiplied by the total number of base points. These multipliers were based on streak, length of time the player had been playing, and well-timed power-up usage. Depending on length, a streak could offer anywhere between a 1x and a 10x multiplier. Progress multipliers (which increased based on length of play) started at 1x but could grow to up to 3x. Activating one power-up was a temporary 2x multiplier, but activating both at the same time was 5x. To give an example of how this works, consider the first deflection of the game, which scores:

\[300 = 300 \times 1 \times 1 \times 1\]

(Score increase = base * deflection multiplier * progress multiplier * power-up multiplier)

Compare that with making 30 deflections in a row while having both power-ups activated:

\[45,000 = 300 \times 10 \times 3 \times 5\]

(Score increase = base * deflection multiplier * progress multiplier * power-up multiplier)

Since it is possible to achieve this multiplier stack only two minutes into the game, skillful players are able to significantly differentiate themselves and compete with each other for high-score (Table 2, Row 12).

In summary, by tracking and displaying score, we increased players' engagement and desire to replay the game. Having a goal (obtaining the highest score) gave players a win condition (beating their previous high score or that of a friend). It also provided a feedback loop which helped new players learn the game. Power-ups and a new enemy type increased variety and choice, increasing fun and replayability. Using heuristics as a guide, we made changes which substantially deepened the overall play experience.
5.3.3 Implementing Sound Design

Knowing the music festival would be loud and chaotic, we chose not to implement sound effects or music on our first iteration. We also had a tight delivery schedule, so discarding sound allowed us to focus on core gameplay and physical design first. But wanting to deliver the most immersive, engaging version *Global Warning*, we knew we would implement sound eventually.

Adding sound provided an entirely new sense through which to experience the game (Table 2, Row 13). Additionally, sound effects would increase immersion, as well as provide an additional layer of feedback to let players know if they were acting correctly or incorrectly. Not only would players be rewarded with score, but they would receive audible feedback (Table 2, Row 14). Sound effects like a pleasant chime for success, an irritating crash for failure, and voice cues that say things like "multiplier bonus activated" are clear ways for players to gauge their moment-to-moment progress.

Music can also be emotionally evocative and useful for establishing a game's mood (Table 2, Row 15). The addition of an ever present drum that increases in tempo like a thumping, anxious heartbeat provided significant tension for our players.

In summary, adding sound and music allowed us to stimulate an entirely new sense. This contributed mood and created a more immersive experience. Additionally, sound effects allowed us to provide feedback to player actions in an easily digestible way. Without looking away from the game, players could hear when they had made a good or bad move.

5.3.4 Developing Basic Analytics

Observing every play session at Flow was impossible, and as the game found additional venues, we needed a more practical way of getting data. Programmatically logging game data would allow us to observe play sessions in bulk and generate more thorough quantitative analyses on the gameplay experience. This improvement to our data gathering methods would hopefully help with future iterations of the game.

We decided to focus on a few core metrics: number of play sessions, session length, score, deflection count, max streak, and power-up usage. Number of play sessions would track how many times the game had been played, eliminating our need to rely on estimates or keep track ourselves. From session length, we could determine how long the average game lasted then tweak difficulty parameters accordingly to reach a target length. Tracking score would be important for maintaining the high score leaderboard. It would also help us differentiate between highly skilled players and beginners. Deflection count would tell us how far players progressed in the game, while max streak would help gauge performance. High streaks would mean players understood the game and were skilled, while low streaks might signal that the players were having issues understanding the game or it was too difficult.
Chapter 6

Discussion and Recommendations

The depth and breadth of lessons learned during the development of Global Warning are too much for one thesis, but below, I have condensed our key findings into recommendations that I believe will be most beneficial to other designers. In order to be applicable to a variety of projects, they are presented broadly.

- Communication is Paramount

Clear and explicit communication is important for a smooth user experience. With a wide range of players comes a wide range of experience, competence, and skill in games, and designers cannot expect them to share the same intuitive understanding. This, of course, is a tricky balance. Designers must provide players with everything they need to start playing, but they also must allow players to discover things on their own. What is most important is that designers are clear about when they are intentionally giving information and when they are withholding.

When players could not figure out how to play (or even start) Global Warning, it was not because we were allowing players to discover something on their own. It was a failure in basic usability. Designers must understand that few players will read instructions, and subtlety is often overlooked. Complementing written instructions with strong audio and visual cues is a much more reliable way of teaching. Additionally, it is vital that once play has begun, players understand their in-game status. Uncertainty about their health, score, and basic goals will severely limit players’ enjoyment.

- Playtest Early and Often

Playtests should be performed early and often, using as large and varied a test group as possible. This will provide insight into how players from different demographics perceive and interact with your game. Even more important, however, is to resist becoming defensive toward the feedback you receive. Players will be ruthless, both intentionally and unintentionally, as they reveal your game’s flaws. While this can be painful, the ability to remain objective and listen to what players are saying will result in a far superior product. Criticism and failure are opportunities to make your game better, if properly considered. The most vital changes we made were the result of playtests. Color combining was originally the mechanic we implemented for player two, but testers hated it. We thought it would be fun, but playtesting proved it to be confusing and overly difficult. We abandoned it in favor of color matching, and the game quickly became much more intuitive and fun.

Playtests are not all bad news. They also illuminate what is most engaging and unique about your game, allowing you to focus in that direction. When color matching replaced color combination, players responded far more positively. The mechanic was much simpler but still required some concentration, which made it very engaging. Use playtests to
learn the strengths and weaknesses of your game, and make changes where necessary. Pairing playtest findings with well-established game design heuristics will also help guide decision making. We found a lot of success referencing Sweeter and Wyeth’s GameFlow Model to better understand our playtest data and find actionable solutions.

- Innovation Versus Invention

Game designers do not need to invent from scratch, and many successful games arise from simple variations of a classic or proven idea. Identify what is lacking in a game or genre and try to build a game that addresses that lack. In business, this is the process of "finding your niche." Breakout was a single-player adaptation of Pong, and Warlords was a combination of Breakout and Quadrabong. While these games had their roots in imitation, each was different enough to find success in the market.

The primary innovation of Global Warning was adding a second layer to the core mechanic of paddle-and-ball games, deflection. This allowed us to fit two different player roles into a shared paddle avatar, enabling cooperation through interdependence. It was a relatively minor change that created a very different feeling game, demonstrating that small variations to an existing game is a valid way of designing new ones. Few players made the connection between Global Warning, Pong, and other paddle-and-ball games, and many commented that the game felt fresh and original. I believe this method can be a great starting point for both young and experienced designers.

- Asymmetric Mechanics are Worth Exploring

Asymmetric mechanics provided a lot of added value to Global Warning, especially in terms of replayability and moderating differences between player groups. With two unique roles, players frequently switched positions and played another game from the other perspective. And since each role presented a different level of challenge, it bridged the gap between players of different skill levels. Parents could play with children, and serious gamers could play with non-gamer friends.

With asymmetric player abilities, we were also able to strengthen cooperation through interdependence. The gameplay experience became more social and more engaging when players had to rely on each other. It also underscored our theme of climate change being a global problem we must face together. Overall, asymmetric mechanics provided a lot of advantages and uniqueness to Global Warning, and it is worth exploring for designers what this style of gameplay can bring to their game.
Chapter 7

Conclusion

Although the process of developing *Global Warning* was extremely challenging, it was also extremely rewarding, and I consider it one of my proudest achievements. Not only did my knowledge of game design grow but also my competence in programming, electronics, carpentry, and product design. Physical games provide so many interesting hurdles that digital games do not, and each one was a learning opportunity. The game marks an exciting and fitting culmination to my studies at Aalto.

Ultimately, I believe we achieved our goal of creating a physical computing game that engaged a diverse festival audience. The five pillars we established based on characteristics of popular arcade games definitely helped focus and execute our design. Of course, the game still has its issues, especially when it comes to usability and the first-time player experience. There are also ample opportunities to add more depth – new enemy types, new player abilities, boss battles, additional sound effects and animations, etc. For now, however, work on *Global Warning* is complete.

Since completion of the second iteration improvements in May 2019, *Global Warning* has been shown at four exhibitions: Kontula Electronic, an arts and electronic music festival in Helsinki; Sónar+D, a music and technology conference in Barcelona; an Aalto Games, Art & Science exhibition at the Helsinki Central Library; and in the lobby of Rovio Entertainment, the mobile game company behind the *Angry Birds* franchise. At the time of writing, *Global Warning* has been played over 5000 times, which I never would have expected when first embarking on this project. And while the thought of showing at more festivals is exciting, we are currently trying to find a more long-term home for the game. Having it join the collection at Wonderville, alongside Robin’s *Line Wobbler* and other independent arcade games, would be a wonderful capstone to the project.
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Flow Festival. Flow Festival takes place this weekend in Helsinki's Suvilahti. 7 August 2018.

December 2019.


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